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THINNING AND PRUNING PONDEROSA PINE FOR THE SUPPRESSION AND PREVENTION OF ELYTRODERMA NEEDLE DISEASE (*Elytroderma deformans* (Weir) Darker) ON THE BITTERROOT NATIONAL FOREST:

ESTABLISHMENT REPORT AND FIRST RE-MEASUREMENT

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INTRODUCTION

Elytroderma deformans (Weir) Darker causes a serious needle disease of pines in Western North America (Childs et al. 1971) and is considered the most important needle disease of ponderosa pine in Montana. It is a fungus that was first described by Weir (1916). *E. deformans* infects current year's needles during mid- to late-summer; the following spring, these needles turn red and fruiting bodies of the fungus (hysterothecia) are produced on red needles in mid- to late-summer. Hysterothecia mature and produce spores which infect the current year's needles during periods of high humidity, thus completing the cycle. After the spores are released, the infected needles are shed in the fall and throughout the winter. Vegetative growth of the fungus can invade branch and twig tissue. Once twigs have become infected, they will usually flag again each spring for many years and soon curve upwards. Vigorous infected branches may develop into dense, globose witches' brooms. These brooms often survive and grow for many years, but flagged twigs on un-broomed branches gradually decline and die after just a few years (Childs 1968).

Elytroderma needle blight is most damaging in trees of low vigor with poor crowns; however, the disease is often more conspicuous in good crowns (Childs et al. 1971). If a tree is lightly infected, growth effects are probably negligible. When the infection level is moderately severe in mature trees, the crowns become thin with shortened needles and the trees are reduced in vigor. It is assumed moderately and severely infected trees experience some level of growth loss, but these effects have not been adequately quantified. Direct mortality from *E. deformans* has been observed in both precommercial- and commercial-sized trees in areas with long-term heavy infections. Moderately infected trees are

also susceptible to bark beetle attacks and may be more susceptible to root disease (Childs 1968). The longer a tree is severely infected with *E. deformans*, the less attractive it becomes to bark beetles (Childs et al. 1971).

Systemic infections from *E. deformans* can occur in the bole of the tree and not in the branches, so trees can display the twisting, resinous symptoms on the boles, but have no flagging on any of the branches. Young pine trees have needles borne directly on the bole of the tree, which can be an infection court for *E. deformans*. There are no second year needles on the bole to turn red to indicate infection because once the infected needles are cast, there will be none to replace them. If systemic infection occurs through these needles, the only way to detect it is from the characteristic bending and twisting of the bole and the necrotic lesions under the bark as seen in systemically infected branches. Childs (1968) discovered necrotic lesions in trunks of small trees that were not associated with branch flagging, and Roth (1959) discusses evidence of vegetative spread of the disease up and down trunks of smaller trees.

Elytroderma needle blight has been documented in the literature as a cyclic disease (Scharpf and Bega 1981, 1988; Childs et al. 1971; Childs 1968). It usually exists at endemic levels, but under certain conditions epidemic outbreaks can occur on some sites. In several areas in western Montana this disease has been ongoing for years; in some places for at least 50 years (Waters 1957). It is a management concern in these localized areas; various outbreaks on the Bitterroot National Forest south of Missoula and Gette Lake on the Flathead Indian Reservation north of Missoula are approaching such longevity as to effect management decisions.

E. deformans has been causing significant damage to young 20-year old ponderosa pine stands since their establishment in the Lick Creek area on the Darby Ranger District of the Bitterroot National Forest. These stands consist of both planted and natural ponderosa pine. At the request of the district, Forest Health Protection (FHP) first visited the area in 1999 (Lockman 1999) and then again in 2003 (Lockman and Jackson 2003). Elytroderma brooms and needle casting are present in the younger trees, and the scattered overstory trees are lightly infected. Many of the pine boles of the younger trees are twisted and bent with no directional pattern to the bending apparently due to bole infections by *E. deformans*.

Maintaining proper stocking density of young stands is important in minimizing impacts from *E. deformans*; if *E. deformans* is already present within an older stand, thinning appears to exacerbate it, at least in the short term (Childs et al. 1971). Thinning ponderosa pine stands early and keeping them thinned is the present management recommendation in areas prone to infection by *E. deformans*. There is debate about what spacing is best to minimize new infections and to lessen the impact from this disease. There is also debate about the effectiveness of pruning to minimize new infections. There is no conclusive research indicating that pruning is effective, but it has been occasionally recommended in the past. Because most of the Elytroderma infections occur in the lower crowns, operational pruning may be effective in helping to control this disease; lifting the crowns would remove the most susceptible foliage.

The Darby Ranger District was preparing to precommercially thin these young stands in Lick Creek, which offered an opportunity to look at the effects of various spacings of thinning and pruning on Elytroderma needle disease. With the assistance of the District, treatment areas were determined and FHP established plots to monitor the effects of thinning and pruning on Elytroderma needle disease.

METHODS

Location of Stands

The study site is on the Darby Ranger District of the Bitterroot National Forest, north of Lake Como. Twelve stands were scheduled for

thinning and were large enough to install monitoring plots. Stands 2.12, 2.11, 2.10, 2.7, 2.4, 2.5, 2.6, 2.9, and 2.13 are located off Forest Road 5623, and stand 2.1 is located off Forest Road 5608. Stands 2.4A and 2.3 are accessed by foot from Forest Road 5621. Seven stands are located in Sections 24 and 25 of T32N, R22W (stands 2.10, 2.7, 2.4, 2.5, 2.6, 2.9, and 2.13); four stands are located in Section 30 of T4N, R21W (stands 2.12, 2.11, 2.4A, and 2.3); and one stand is located in Section 19 of T4N, R21W (stand 2.1).

Treatments

Treatments were: 1) thin to 12x12 feet spacing (T12; 52 total acres); 2) thin to 18x18 feet spacing (T18; 51 total acres); 3) thin to 12x12 feet spacing plus pruning (T12P; 49 total acres); and 4) control with no thinning or pruning (C; 41 total acres). The maximum height of branches to be pruned was the lesser of 8 feet or ½ of the total height of the tree. We used a Balanced Incomplete Block Design and randomly assigned paired treatments to the twelve stands available for the study (see Table 1). Each treatment was replicated six times.

TABLE 1. Assignment of paired treatments to each of the twelve stands available for the Elytroderma thinning and pruning study.

Paired treatments[1]	**Stand assignments**[1]	**Stand assignments**[1]
T12 T18	**2.11** (split into 2.11A and 2.11B)	**2.9** (split into 2.9B and 2.9A)
T12 T12P	**2.1** (split into 2.1A and 2.1B)	**2.4** (split into 2.4B and 2.4C)
T12 C	**2.7** (split into 2.7 and 2.7Control)	**2.4A** (split into 2.4A and 2.4AControl)
T18 T12P	**2.13** (split into 2.13A and 2.13B)	**2.6** (split into 2.6B and 2.6A)
T18 C	**2.12** (split into 2.12 and 2.12Control)	**2.3** (split into 2.3 and 2.3Control)
T12P C	**2.10** (split into 2.10 and 2.10Control)	**2.5** (split into 2.5 and 2.5Control)

1 Each stand was split in half and randomly assigned one of the two paired treatments. Several Control assignments were switched after this random selection in order to accommodate concerns of the district.

Plot Locations within Stands

The approximate center of each stand half was located and marked on the stand map; the azimuth and distance from a corner of each stand to this center mark was then determined. After pacing to the location, a piece of rebar was installed.

Pre-treatment Data

Pre-treatment data were collected in July 2004 after disease symptoms had fully developed. These stands are at an elevation of 4600 feet to 5200 feet, so disease development is chronologically later than at lower elevations.

The boundary of a 1/3 acre circular plot was flagged (radius equal to 60 feet), using the rebar as the center of the plot. Fifty potential crop trees were located by walking around this plot starting from the north and moving clockwise, spacing approximately 12 feet between each tree, and keeping within the flagged margins. If fifty potential crop trees could not be located within the flagged margins of the plot, then the margin was expanded until fifty trees were located. These trees were permanently tagged at dbh (diameter at breast height) facing plot center in the control plots, and temporarily flagged in the plots scheduled for treatment. Data recorded for each tree were: diameter at breast height (dbh); total tree height; crown ratio, crown class, lowest

live crown height; and any damage and severity of damage using Northern Region Stand Exam protocols (Anonymous 1986); and Elytroderma infections.

Elytroderma infections were evaluated three different ways:

1) First, each crown was rated for systemic infections with a tree based system as used in the Hawksworth's rating system for dwarf mistletoe infections (Hawksworth 1977):

Divide live crown into thirds: top, middle, and bottom. Each third receives a rating of 0= no systemic infections; 1= ½ or less of total branches have systemic infections; 2= more than ½ of the total branches have systemic infections.

2) Each crown was also given an overall rating of red foliage using:

0= <5% red foliage; 1= 5% to 15%; 2= 16 to 25%, 3= 26 to 35%; 4= 36 to 45%; 5= 46 to 55%; 6= 56 to 65%; 7= 66 to 75%, 8= 76 to 85%; 9= >85% of crown is red.

3) And the third rating was for evaluating stem infections from Elytroderma:

0= no visible stem infection; 1= light stem infection, appears to have recovered; 2= obvious stem infection with twisting and deformity.

In addition to the tree data, plot level information was also recorded which included slope and aspect at plot center, as well as GPS location.

Post-treatment Data

Thinning and pruning of the stands were accomplished with a contract crew and were completed by September 2004, at which time post-treatment data were collected. The control plots did not receive a treatment, and thus did not need data collected again in 2004. For the treatment plots, the margin of a 1/3 acre circular plot was again flagged, using the rebar as the center of the plot. Fifty crop trees were located by walking around this plot starting from the north and moving clockwise, and keeping within the flagged margins. If fifty trees could not be located within the flagged margins of the plot, then the margin was expanded until fifty trees were located. These trees were permanently tagged at dbh facing plot center. Data recorded for each tree were: dbh; total tree height; crown ratio; lowest live crown height; and any damage and severity of damage using Northern Region Stand Exam protocols (Anonymous 1986). Crown class was determined to have no value after treatment, so was not included in the post-treatment data collection. Elytroderma was not evaluated at this measurement. The pre-treatment Elytroderma ratings will be used as the initial infection levels for all plots.

Remeasurement

The first remeasurement was done in July 2006, to allow for a complete infection cycle of *E. deformans* to occur after stand treatment. In July 2006, each plot was revisited; tree tags were verified and Elytroderma infections were evaluated using the same criteria as at plot establishment. No growth data were collected at this measurement.

Statistical Analysis

The statistical software SAS, Mixed Procedure (Littell et.al 2006) was used to analyze data. The differences between treatment means were tested using the F-test in the Type 3 Tests of Fixed Effects. T-test of Differences of Least Squares Means, with Tukey-Kramer adjustment for multiple comparisons, was used for further analysis when the F-test was significant. We used an alpha level of 0.10 for all statistical tests.

RESULTS

Plot Establishment

Pre-treatment plot means are shown in Table 2. Two pieces of collected data were determined to be of minimal value and are not included in the analysis. These are crown class and crown ratio. All remaining tree and Elytroderma data collected in the field are included. Also, two new variables were created- elysum and elypres. These two data are simplifications of the Elytroderma information collected in the field. Elysum is the summation of the ratings for systemic infections, and elypres is a simple measure of presence or absence of systemic infections.

TABLE 2. Pre-treatment means by plot at plot establishment in July 2004.

Stid[1]	Treat[2]	N[3]	Dbh[4]	Ht[5]	Lcht[6]	Etop[7]	Emid[8]	Ebot[9]	ECrown[10]	EStem[11]	ElySum[12]	ElyPres[13]
2.11A	T12	50	6.00	30.06	12.24	.00	.04	.51	.92	.06	.55	.48
2.1B	T12	51	3.62	14.63	2.12	.00	.00	.02	1.00	.10	.02	.02
2.4A	T12	50	3.92	17.76	5.78	.00	.00	.34	1.16	1.19	.34	.34
2.4B	T12	50	3.56	17.32	5.52	.00	.10	.66	1.24	.69	.76	.60
2.7	T12	50	4.93	21.54	7.52	.00	.10	.65	1.34	.58	.75	.58
2.9B	T12	50	5.70	25.24	5.78	.00	.00	.02	1.06	.02	.02	.02
2.10	T12P	50	4.65	21.14	5.28	.00	.00	.19	.72	.10	.19	.18
2.13A	T12P	50	4.08	18.72	4.48	.00	.00	.04	1.00	.04	.04	.04
2.1A	T12P	50	4.08	16.18	2.36	.00	.00	.00	1.06	.10	.00	.00
2.4C	T12P	50	3.49	18.37	5.93	.00	.04	.34	.96	.28	.38	.32
2.5	T12P	49	3.73	17.63	5.16	.00	.00	.63	1.04	.41	.63	.57
2.6B	T12P	50	3.60	18.68	5.44	.02	.04	.58	1.06	.65	.64	.46
2.11B	T18	50	4.38	20.51	6.54	.00	.00	.12	1.38	.27	.12	.12
2.12	T18	50	4.71	20.96	6.58	.00	.01	.13	1.50	.06	.14	.14
2.13B	T18	50	4.61	19.96	4.58	.00	.00	.01	1.18	.00	.01	.02
2.3	T18	49	3.62	16.82	3.54	.00	.00	.26	1.22	.13	.26	.24
2.6A	T18	50	4.14	17.60	4.36	.00	.00	.30	1.10	.08	.30	.30
2.9A	T18	50	3.03	16.08	4.04	.00	.00	.05	1.18	.00	.05	.06
2.10C	C	50	4.44	21.48	5.71	.00	.00	.00	1.04	.04	.00	.00
2.12C	C	50	4.45	22.20	6.82	.00	.00	.00	1.28	.00	.00	.00
2.3C	C	51	2.82	13.20	2.96	.00	.02	.10	1.06	.10	.12	.12
2.4AC	C	50	4.38	19.00	5.26	.00	.02	.33	1.08	.59	.35	.30
2.5C	C	50	2.67	13.88	4.18	.00	.00	.06	1.16	.11	.06	.06
2.7C	C	50	3.85	19.48	7.12	.00	.11	.65	1.64	.42	.76	.54

1 Stid= stand identification number used by Darby Ranger District.
2 Treat= Treatment; T12= 12x12 thinning, T12P= 12x12 thinning plus pruning, T18= 18x18 thinning, C= control.
3 N= number of trees sampled per plot.
4 DBH= diameter at breast height.
5 Ht= total tree height.
6 Lcht= lowest live crown height.
7 Etop= Elytroderma rating in top 1/3 of crown.
8 Emid= Elytroderma rating in middle 1/3 of crown.
9 Ebot= Elytroderma rating in bottom 1/3 of crown.
10 Ecrown= portion of red needles in crown.
11 Estem= Elytroderma rating in stem of tree.
12 Elysum= Etop+Emid+Ebot
13 ElyPres= if Elysum>0, then tree given a 1 for ElyPres, otherwise=0.

Average pre-treatment plot conditions of the six replications were combined by treatment, and an F-test for differences between treatment means for each plot variable was done. Table 3 contains the information from this analysis for the tree measurements collected before treatment. The probability of an equal or larger F value for dbh and height was > 0.10 (Prob. F >0.10), so no treatment effect was found, but there is a possible treatment effect for lower crown height (lcht; Prob.F =0.1030). When the treatment effect for lcht is analyzed further using a T-test of differences of least squares means, significance was found between treatment T12 and T18. The adjusted means for the tree variables indicate the trees in the stands selected for the T12 treatment are in general bigger than the trees selected for the other treatments, but the adjusted probability of an equal or larger T value > 0.10 (Adj. Prob. T > 0.10).

TABLE 3. Table of treatment effects for tree measurements at time of pre-treatment (July 2004).

Dependent =	DBH[1]	Ht[2]	Lcht[3]
-2 log likelihood	51.5	123.9	89.8
AIC	63.5	135.9	101.8
Treatments/sig	0.2217	0.2262	0.1030[4]
Treatment T12 Adjusted means	4.6315	21.1619	6.3804
Treatment T12P Adjusted means	3.9894	19.2207	5.4785
Treatment T18 Adjusted means	4.0281	17.7792	4.4928
Treatment C Adjusted means	3.7609	18.2449	5.1982

1 DBH= diameter at breast height.
2 Ht= total tree height.
3 Lcht= lowest live crown height.
4 Significant at α<=0.10

Tables 4a and 4b contain the analysis data for the Elytroderma measurements collected before treatment. Ecrown, which is the measurement of red foliage throughout the crown, was found to have a significant treatment effect. The T-test for comparisons between the four treatments found a significant difference between treatment T12P and T18 (Adj. Prob. T =0.0240). Trees in the plots selected for the T18 treatment have more red needles in their crowns than trees selected for the T12P treatment. Caution must be used here, as the adjusted means are very small to begin with, and very little change in this measurement would need to occur to change this statistic. Elypres is the measure of presence or absence of systemic infections of Elytroderma. A treatment effect was found for elypres (Prob. F=0.0996). A simple T-test found a significant difference between the control and treatment T12 and between the control and treatment T12P, but no significant adjusted p values were found when all combinations of treatments were compared.

TABLE 4a. Table of treatment effects for Elytroderma measurements at time of pre-treatment (July 2004).

Dependent =	Etop[1]	Emid[2]	Ebot[3]
-2 log likelihood	-200.3	-107.6	-9.4
AIC	-190.3	-95.6	2.6
Treatments/sig	0.3641	0.2147	0.1279
Treatment T12 Adjusted means	0	0.0310	0.3472
Treatment T12P Adjusted means	0.0033	0.0167	0.3270
Treatment T18 Adjusted means	6.07E-20	0.0073	0.1842
Treatment C Adjusted means	-819E-22	0.0250	0.1400

1 Etop= Elytroderma rating in top 1/3 of crown.
2 Emid= Elytroderma rating in middle 1/3 of crown.
3 Ebot= Elytroderma rating in bottom 1/3 of crown.

TABLE 4b. Table of treatment effects for Elytroderma measurements at time of pre-treatment (July 2004).

Dependent =	Ecrown[1]	Estem[2]	Elysum[3]	Elypres[4]
-2 log likelihood	-23.6	0.1	-4.4	-16.5
AIC	-11.6	12.1	7.6	-4.5
Treatments/sig	0.0270[5]	0.1547	0.1490	0.0996[5]
Treatment T12 Adjusted means	1.0925	0.3949	0.3797	0.3238
Treatment T12P Adjusted means	1.0039	0.3022	0.3470	0.2893
Treatment T18 Adjusted means	1.2751	0.1708	0.1902	0.1840
Treatment C Adjusted means	1.1918	0.1354	0.1648	0.1212

1 Ecrown= portion of red needles in crown.
2 Estem= Elytroderma rating in stem of tree.
3 Elysum= Etop+Emid+Ebot
4 ElyPres= if Elysum>0, then tree given a 1 for ElyPres, otherwise=0.
5 Significant at $\alpha<=0.10$

Treatments were completed in September 2004, and crop trees had to be located on the treated plots, permanently tagged, and measured for dbh, height, and lower crown height. Plot means for these 3 variables are shown in Table 5. Average plot conditions of the six replications were combined by treatment, and a test for differences between treatment means for the new tree variables was done. The means for these post-treatment trees should be very similar to the means for the pre-treatment trees.

TABLE 5. Table of raw means for post-treatment tree measurements (Sept. 2004).

Stid[1]	Treat[2]	N[3]	Dbh[4]	Ht[5]	Lcht[6]
2.11A	T12	50	5.93	29.84	11.58
2.1B	T12	51	3.55	14.08	2.14
2.4A	T12	50	4.04	18.10	6.16
2.4B	T12	51	2.98	15.51	5.16
2.7	T12	50	5.23	23.42	7.30
2.9B	T12	50	5.63	25.02	5.90
2.10	T12P	50	4.18	19.54	8.08
2.13A	T12P	50	3.63	16.66	7.32
2.1A	T12P	50	4.09	16.34	8.18
2.4C	T12P	50	2.92	13.28	5.88
2.5	T12P	50	3.59	16.60	7.64
2.6B	T12P	51	3.79	19.51	8.06
2.11B	T18	50	4.37	21.48	7.30
2.12	T18	50	4.87	24.54	7.54
2.13B	T18	50	4.97	20.74	4.46
2.3	T18	50	3.41	15.62	3.32
2.6A	T18	51	3.93	17.16	4.98
2.9A	T18	50	3.18	15.46	4.38
2.10C	C	50	4.44	21.48	5.71
2.12C	C	50	4.45	22.20	6.82
2.3C	C	51	2.82	13.20	2.96
2.4AC	C	50	4.38	19.00	5.26
2.5C	C	50	2.67	13.88	4.18
2.7C	C	50	3.85	19.48	7.12

1 Stid= stand identification number used by Darby Ranger District.
2 Treat= Treatment; T12= 12x12 thinning, T12P= 12x12 thinning plus pruning, T18= 18x18 thinning, C= control.
3 N= number of trees sampled per plot.
4 DBH= diameter at breast height.
5 Ht= total tree height.
6 Lcht= lowest live crown height.

When analyzed (see Table 6), no significant treatment effect was found for dbh or height. A very significant treatment effect was found for lower crown height (Prob. F=0.0079). T-tests for comparison of treatments found significant differences between T12P and T12 (Adj. Prob. T=0.1095); between T12P and T18 (Adj. Prob. T=0.0092); and between T12P and Control (Adj. Prob. T=0.0145). These comparisons show that the pruning was successful at lifting the crowns significantly higher than the crowns in the other three treatments.

TABLE 6. Treatment effects for tree measurements immediately after treatment (Sept. 2004).

Dependent =	DBH[1]	Ht[2]	Lcht[3]
-2 log likelihood	55.3	129.0	91.5
AIC	67.3	141.0	103.5
Treatments/sig	0.2433	0.2106	0.0079[4]
Treatment T12 Adjusted means	4.5754	21.2893	6.2233
Treatment T12P Adjusted means	3.7932	18.0977	8.1761
Treatment T18 Adjusted means	4.0351	18.0442	4.9682
Treatment C Adjusted means	3.7464	17.9255	5.2041

1 DBH= diameter at breast height.
2 Ht= total tree height.
3 Lcht= lowest live crown height.
4 Significant at $\alpha <= 0.10$

2006 Remeasurement

Plot means for Elytroderma measurements are shown in Table 7. Average plot conditions of the six replications were combined by treatment, just like at plot establishment, and an F-test for differences between treatment means for each plot variable was done. Four trees died after plot establishment: one in stand 2.7; two in 2.13A; and one in 2.7C. A cause of mortality could not be determined for any of these four trees.

Table 7. Treatment means for 2006 Ely measurements.

Stid[1]	Treat[2]	N[3]	Etop[4]	Emid[5]	Ebot[6]	ECrown[7]	EStem[8]	ElySum[9]	ElyPres[10]
2.11A	T12	50	.00	.12	.68	1.06	.16	.80	.60
2.1B	T12	51	.00	.00	.04	.63	.02	.04	.04
2.4A	T12	50	.00	.02	.16	.98	.66	.18	.18
2.4B	T12	51	.00	.14	.43	1.14	.49	.57	.39
2.7	T12	49[11]	.00	.16	.69	1.14	.12	.86	.66
2.9B	T12	50	.00	.00	.00	.88	.00	.00	.00
2.10	T12P	50	.00	.00	.08	.86	.02	.08	.08
2.13A	T12P	48[11]	.00	.00	.02	.56	.02	.02	.02
2.1A	T12P	50	.00	.00	.00	.12	.00	.00	.00
2.4C	T12P	50	.04	.08	.14	.90	.66	.26	.14
2.5	T12P	50	.00	.00	.20	.94	.42	.20	.20
2.6B	T12P	51	.00	.00	.22	.71	.39	.22	.22
2.11B	T18	50	.00	.02	.30	.98	.04	.32	.30
2.12	T18	50	.00	.00	.00	.48	.00	.00	.00
2.13B	T18	50	.00	.00	.00	.70	.00	.00	.00
2.3	T18	50	.00	.02	.28	.98	.02	.30	.22
2.6A	T18	51	.00	.00	.22	.86	.16	.22	.22
2.9A	T18	50	.00	.00	.00	.96	.06	.00	.00
2.10C	C	50	.00	.00	.00	1.04	.04	.00	.00
2.12C	C	50	.00	.00	.02	.70	.00	.02	.02
2.3C	C	51	.00	.00	.25	.94	.12	.25	.22
2.4AC	C	50	.00	.06	.36	1.08	.34	.42	.30
2.5C	C	50	.00	.00	.02	.94	.04	.02	.02
2.7C	C	49[11]	.02	.12	.43	1.04	.29	.57	.34

1 Stid= stand identification number used by Darby Ranger District.
2 Treat= Treatment; T12= 12x12 thinning, T12P= 12x12 thinning plus pruning, T18= 18x18 thinning, C= control.
3 N= number of trees sampled per plot.
4 Etop= Elytroderma rating in top 1/3 of crown.
5 Emid= Elytroderma rating in middle 1/3 of crown.
6 Ebot= Elytroderma rating in bottom 1/3 of crown.
7 Ecrown= portion of red needles in crown.
8 Estem= Elytroderma rating in stem of tree.
9 Elysum= Etop+Emid+Ebot
10 ElyPres= if Elysum>0, then tree given a 1 for ElyPres, otherwise=0.
11 Number reflects mortality from unknown cause(s). Means were adjusted accordingly.

Table 8a and 8b contain the analysis data for the Elytroderma measurements. Ecrown was found to have a significant treatment effect (Prob. F=0.0146). The T-test for comparisons between the four treatments found a significant adjusted p value for the comparison of treatment T12P with T12 (Adj. Prob. T=0.0133) and between T12P and Control (Adj. Prob. T=0.0367), and was nearly significant between T12P and T18 (Adj. Prob. T=0.1126). Elypres was found to have a significant treatment effect (Prob. F=0.0975). A simple T-test found a significant difference between treatment T12 and each of the other three treatments, but no significant adjusted p values were found when all combinations of treatments were compared. The adjusted mean for elypres in treatment T12 is larger than the adjusted means in the other treatments (Table 8b).

Table 8a. Treatment effects 1.5 years after treatment (July 2006), for Elytroderma measurements only.

Dependent =	Etop[1]	Emid[2]	Ebot[3]
-2 log likelihood	-161.8	-89.8	-19.4
AIC	-149.8	-77.8	-7.4
Treatments/sig	0.4333	0.1425	0.1765
Treatment T12 Adjusted means	-0.0006	0.0556	0.2982
Treatment T12P Adjusted means	0.0068	0.0212	0.1635
Treatment T18 Adjusted means	0.0003	0.0178	0.1385
Treatment C Adjusted means	0.0035	0.0287	0.1564

1 Etop= Elytroderma rating in top 1/3 of crown.
2 Emid= Elytroderma rating in middle 1/3 of crown.
3 Ebot= Elytroderma rating in bottom 1/3 of crown.

Table 8b. Treatment effects 1.5 years after treatment (July 2006), for Elytroderma measurements only.

Dependent =	Ecrown[1]	Estem[2]	Elysum[3]	Elypres[4]
-2 log likelihood	-20.5	-18.5	-10.6	-25.9
AIC	-8.5	-6.5	1.4	-13.9
Treatments/sig	0.0146[5]	0.1843	0.1727	0.0975[5]
Treatment T12 Adjusted means	0.9559	0.1931	0.3513	0.2817
Treatment T12P Adjusted means	0.7026	0.2614	0.1937	0.1579
Treatment T18 Adjusted means	0.8654	0.1005	0.1583	0.1294
Treatment C Adjusted means	0.9126	0.1233	0.1884	0.1261

1 Ecrown= portion of red needles in crown.
2 Estem= Elytroderma rating in stem of tree.
3 Elysum= Etop+Emid+Ebot
4 ElyPres= if Elysum>0, then tree given a 1 for ElyPres, otherwise=0.
5 Significant at $\alpha<=0.10$

DISCUSSION

Plot Establishment

Ideally, no significant differences would exist between the average pre-treatment plot conditions. But this is not the case. There is a significant difference for ecrown, but this may turn out to be a poor measurement of Elytroderma infections. There are many other agents that will turn the needles red, including other needle diseases and feeding by defoliating insects. The more important significant treatment effect is elypres. But, T-tests indicate there is no significant difference when the four treatments are compared to each other.

The significant treatment effect of lcht at pre-treatment indicates the trees in the plots selected for the T12 treatment may be bigger than the trees in the plots selected for the other treatments. This treatment effect on lcht still existed after treatment, but was due to the lower crowns being significantly higher in the pruned plots, thus masking the naturally higher crowns in the T12 plots. It is noteworthy that no treatment effect was found for dbh or height before or after treatment.

2006 Remeasurement

The significant treatment effect for ecrown for the T12P treatment seems logical. Ecrown is a measurement of red needles throughout the crown. Needle diseases, including Elytroderma, tend to be worse in the lower crown and lessen towards the top. Trees that have had the lower crowns removed would also have had that portion of the crown more susceptible to needle diseases removed, thus lowering the overall amount of red needles in the crown. This is a benefit expected in the short term with pruning, and hoped for in the long term. Successive measurements will reveal if this trend continues.

The significant treatment effect for elypres is a bit more confusing. Subsequent T-tests found no significant adj. p values, but there are significant p values before adjustment. These indicate there are more trees with systemic infections from Elytroderma in the T12 treatment when compared to each of the other 3 treatments, but does not indicate that there are more Elytroderma infections within each tree. It will be interesting to see if this trend continues in future measurements.

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